S/X Experiment: DSS 14 Pre- and Post-Track Ranging Calibrations for Mariner 10 Tracking Passes and Associated Problems

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Ground system ranging calibration data for DSS 14 are presented for 1974 Day 12 through Day 150. Associated ranging problems are discussed and recommendations for calibration improvements are presented.

I. Introduction

Ranging calibrations on the ground system at DSS 14 are currently being performed with the Zero Delay Device (ZDD) in the cable configuration that was described in Ref. 1. The ranging calibrations are normally done during pre- and post-calibration periods of Mariner 10 tracking passes at the signal levels and frequencies applicable to the particular tracking pass. These ZDD pre- and post-calibration data are used along with the ground station Z-correction (Ref. 2) and spacecraft radio system bias correction to enable determination of the true range to the spacecraft (Ref. 3).

For purposes of observing the long-term performance of the ZDD, pre- and post-track calibration data have been systematically tabulated at DSS 14 as functions of ambient temperature, signal levels, and other range-dependent parameters. This article presents some of these data in plotted form for convenient reference purposes.

II. Calibration Data

Systematic tabulation of ranging calibration data for the S/X system at DSS 14 was begun after 1974 Day 12 when the new ZDD cable configuration was installed (see Ref. 1). Figures 1 through 10 show plots of the S/X ground system ranging calibrations for Mariner 10 tracking passes from 1974 Day 12 through Day 150.

From Day 47 through Day 85, unexpected Block 4 doppler instability problems made accurate ranging values very difficult to obtain. In this period many system configuration and component changes were implemented by a "Tiger Team" that was formed to investigate and correct the source of the Block 4 receiver doppler instabilities. The doppler instability problem was solved on Day 85, after which the DSS 14 ranging configuration was left virtually unchanged.

From the plotted results, it can be seen that during periods when the range configuration was left unaltered and the same transmitter used, the peak-to-peak range variations were typically within 10 ns for S-band and X-band. It is of interest to observe that the jitter in the data noticeably decreased around the time of Mariner 10 Venus and Mercury encounters, which were Days 36 and 88, respectively.

It can be seen that a significant change of range occurs whenever different transmitters (klystron amplifiers) are used. The ground system S- or X-band group delay is anywhere from 5 ns to 18 ns longer when the 100-kW transmitter is used rather than the 20-kW transmitter. Based on data on the configuration after Day 82, it was found that, when Receiver 3 is used for S-band instead of Receiver 4, the S-band group delay through the DSS 14 ground system is about 28 ns longer. When Receiver 4 is used for X-band instead of Receiver 3, the X-band range delay through the DSS 14 ground system is about 19 ns shorter.

The ground station range delay using the Block 4 system has recently been found to be strongly dependent on received signal level. Variations of delay with signal level have been reported in the following article of this volume (T. Y. Otoshi and P. D. Batelaan, "S/X Experiment: DSS 14 S/X Ground System Ranging Tests). This signal level change is a long-term effect, however, and does not explain the short-term peak-to-peak variations. Some of the short-term variation is correlated with ambient temperature changes. The dependence on temperature, however, is not conclusive because this effect appears to be nonlinear and only a limited amount of reliable data has been available.

III. Discussion of Ranging Problems and Recommendations

It has been found that many variables or factors can affect the ranging calibration values on a day-to-day basis. Therefore, it is important that the ZDD ranging calibration data be applied only for the particular tracking pass for which calibrations were done. Use of some average value for the station delay can result in significant error.

In summary, some of the known major factors that can change ranging calibrations or introduce errors are:

(1) Interchanging transmitters (20-kW or 100-kW klystron).

(2) Interchanging receivers (Receiver 3 or 4 for S or X).

(3) Interchanging exciters (Block 3 or Block 4). The Block 4 exciter is not currently used during pre- and post-calibrations or tracking passes.

(4) Maser gain and tuning.

(5) Ambient temperature.

(6) Replacement of components or cables in the signal path.

(7) Received signal level.

(7) Antenna sag and subreflector defocusing. (This effect cannot be evaluated at DSS 14 with present cable configuration.)

(9) Incorrect range modulation setting. (This effect has not been completely investigated.)

(10) Improper calibration configuration (if there is more than one signal path).

(11) Incorrect voltage-controlled oscillator (VCO) frequency typed into ranging machine by operator.

(12) Reporting acquisition range instead of updated range.

Note that since many of the above factors cannot be controlled or always be known, it is important that pre- and post-calibration data be used for the same day's tracking pass only. The station configuration should not be altered during the tracking pass after calibrations have been performed. Operator errors described by factors (9) through (11) can be minimized only by operator care and long-term familiarity and training of DSS operators on the new S/X system and Mu-2 ranging machine. Data improvement would result from operator verification of correlation voltages. Data with bad correlation voltages should not be reported. Calibrations not within 10 ns or 0.010 μs of previous calibrations indicate a need for recalibration.

It should be possible to eliminate inaccuracies due to factors (11) and (12) by using the Engineering Cal Program[1] (DOI-5399-SP) during the pre- and post-calibration periods. This program contains most of the features of the Monitor Program (DOI-5046-OP), with the addition that doppler phase and ranging calibration processing is done in real time at the station. This calibration program is applicable to the Block 3/PRA and Block 4/Mu-2 configurations. Data from this program can be sent

[1]This program was written by Harvey Marks of Informatics Inc., Canoga Park, California.

to the Mission Control and Computing Center (MCCC) via the high-speed data line. The program is currently in the DSN program library and is now at all stations in the DSN including CTA 21.

It is recommended that for long-term study of ranging and doppler stability data, S/X tests be done at all stations of the DSN with the Engineering Cal Program (DOI-5399-SP).

Acknowledgments

Ray Allis and Ed Cole of the Philco-Ford Corporation performed most of the systematic calibrations and tabulations of data presented in this article. The ranging data were obtained from the teletyped output of the Mu-2 ranging machine which was developed by Warren Martin and programmed by Art Zygielbaum of Section 331.

References

1. Otoshi, T. Y., and Stelzried, C. T., "S/X Experiment: A New Configuration for Ground Range Calibrations With the Zero Delay Device," in *The Deep Space Network Progress Report 42-20*, pp. 57–63, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974.
2. Batelaan, P. D., "S/X-Band Experiment: Zero Delay Device Z Correction," in *The Deep Space Network Progress Report 42-20*, pp. 78–83, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1974.
3. *TRK-2-8 Module of DSN System Requirements Detailed Interface Design Document 820-13, Rev. A.*, July 1, 1973 (JPL internal document).

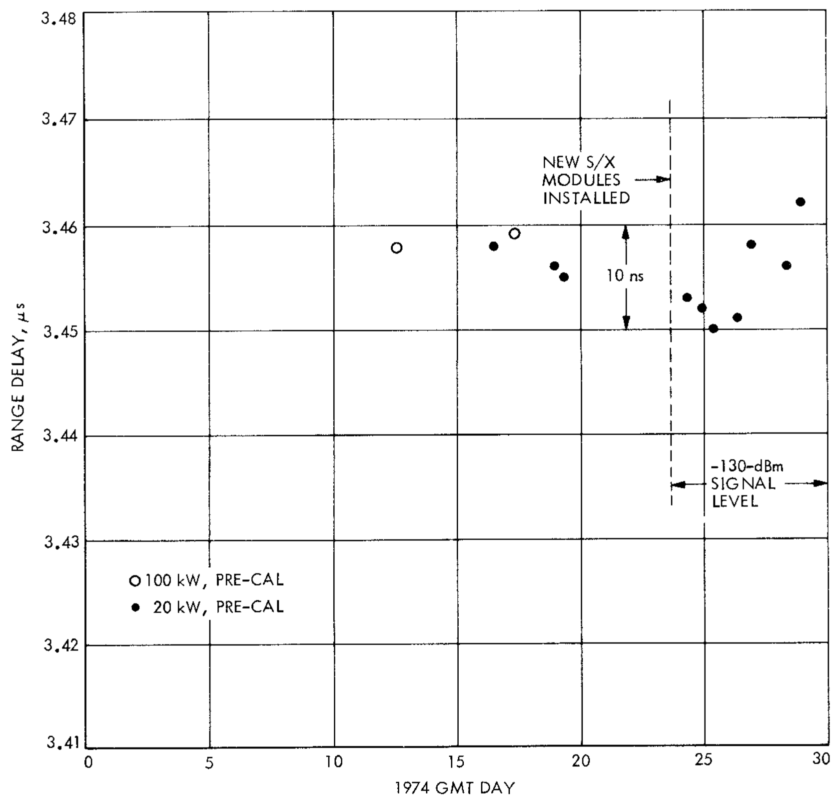

Fig. 1. S-band zero delay range, 1974 Day 1–30 (Jan 1–30)

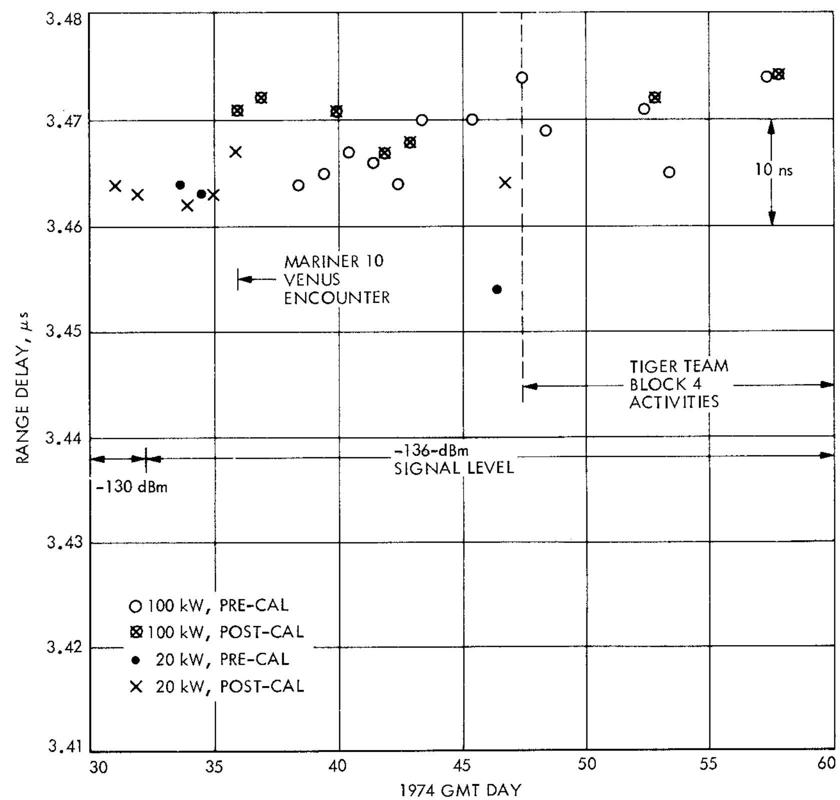

Fig. 2. S-band zero delay range, 1974 Day 30–60 (Jan 30–Mar 1)

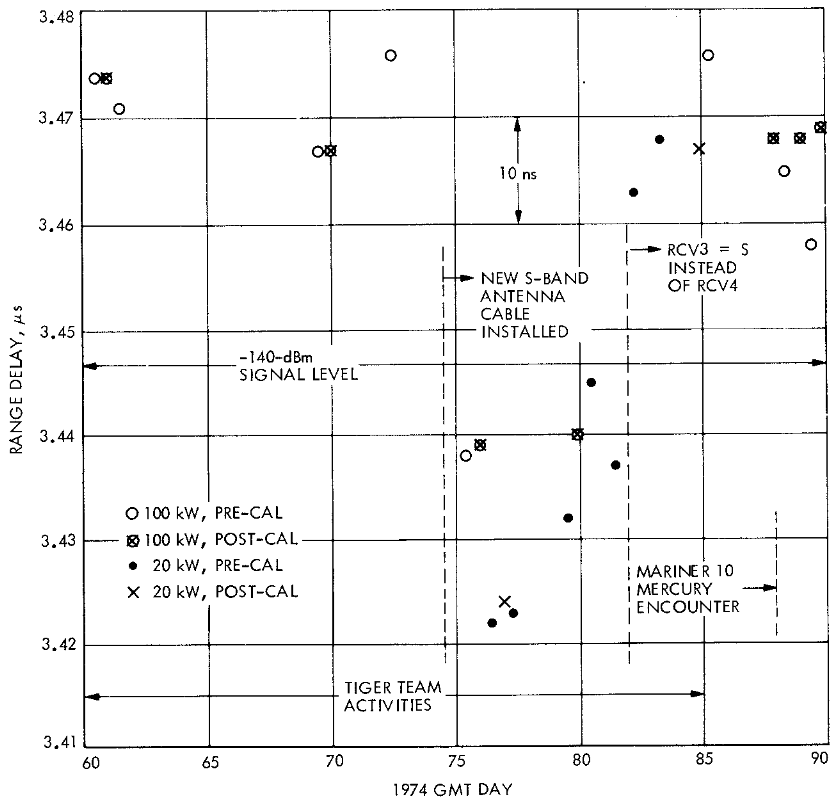

Fig. 3. S-band zero delay range, 1974 Day 60–90 (Mar 1–Mar 31)

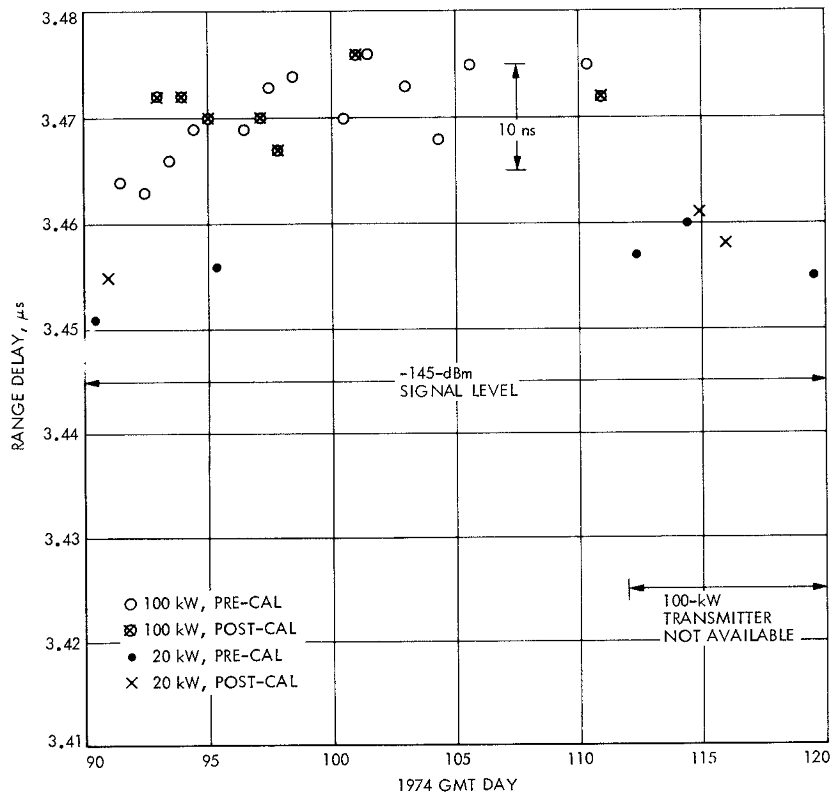

Fig. 4. S-band zero delay range, 1974 Day 90–120 (Mar 31–Apr 30)

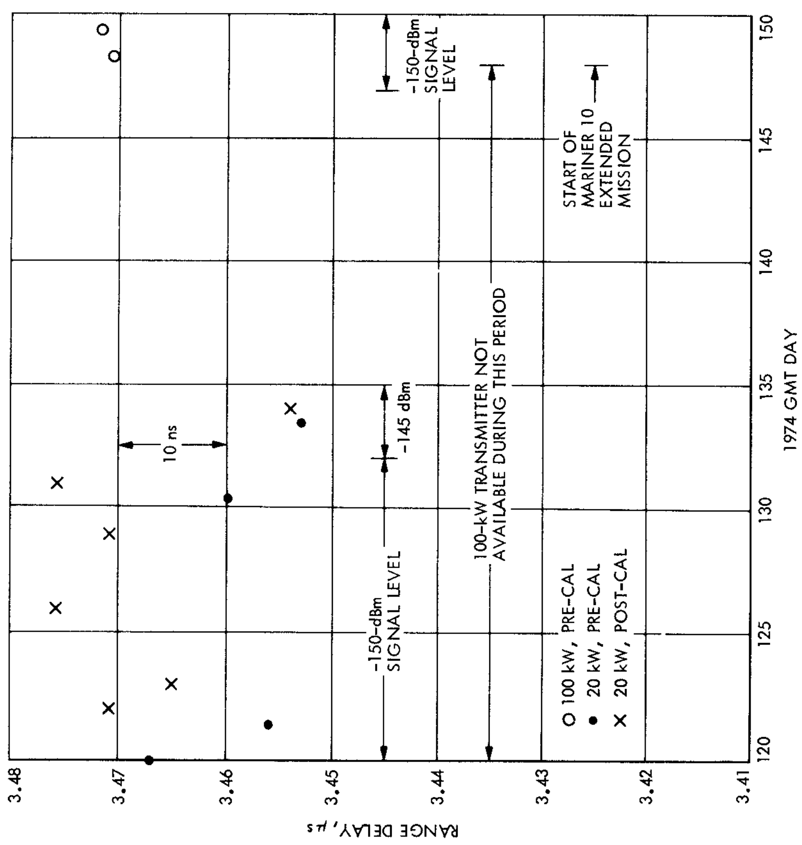

Fig. 5. S-band zero delay range, 1974 Day 120–150 (Apr 30–May 30)

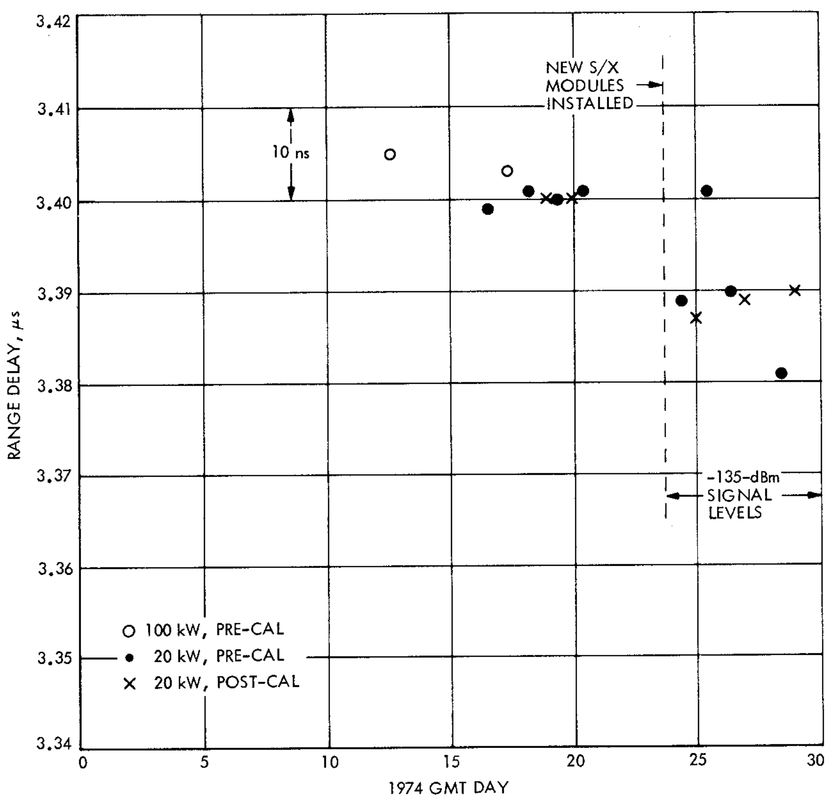

Fig. 6. X-band zero delay range, 1974 Day 1–30 (Jan 1–30)

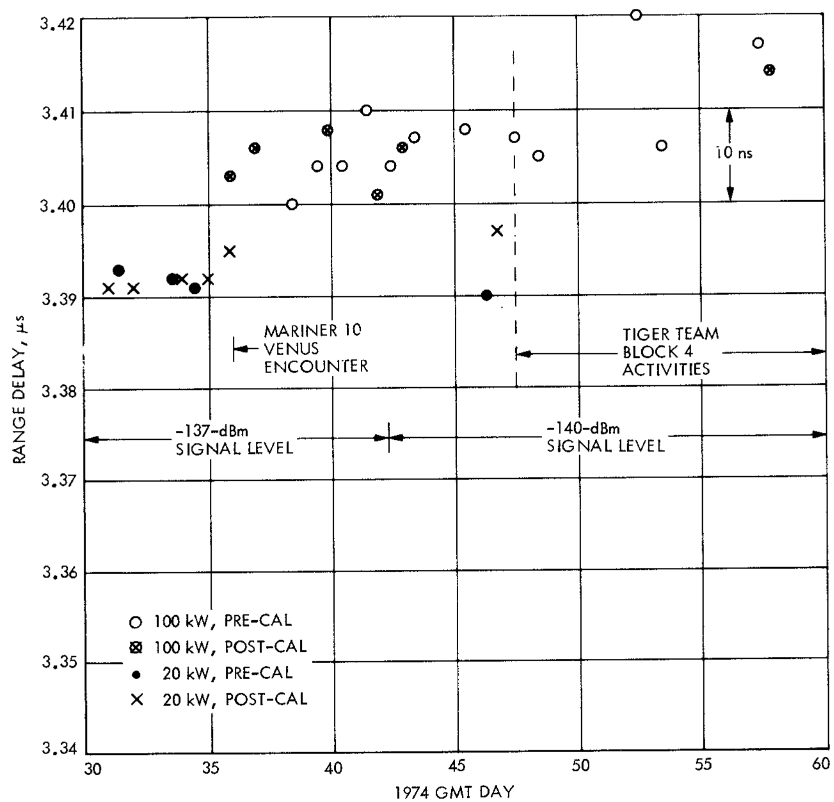

Fig. 7. X-band zero delay range, 1974 Day 30–60 (Jan 30–Mar 1)

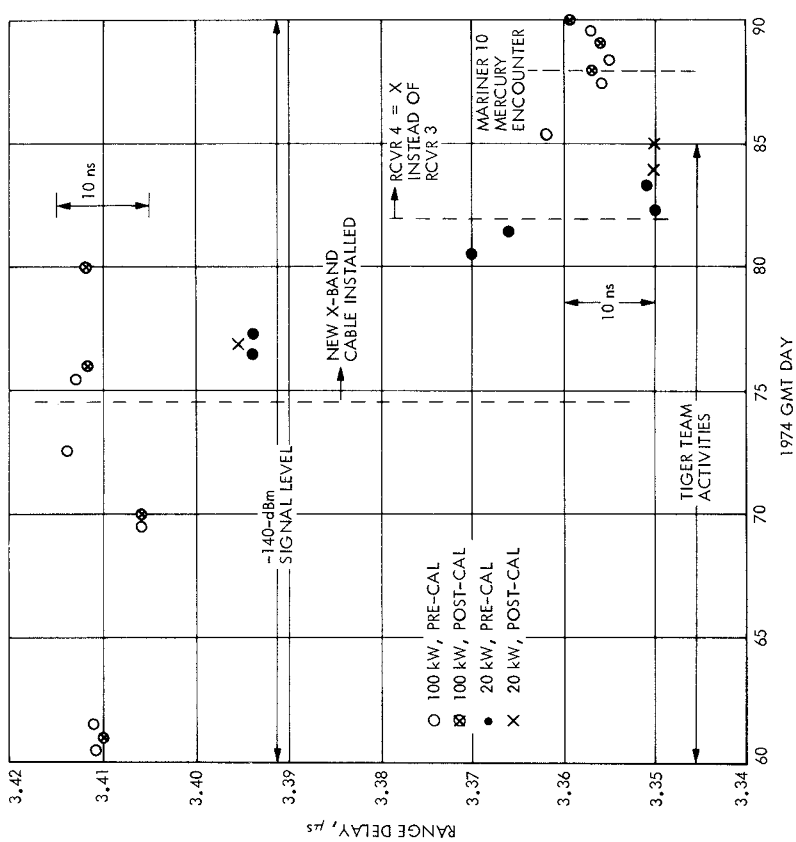

Fig. 8. X-band zero delay range, 1974 Day 60–90 (Mar 1–Mar 31)

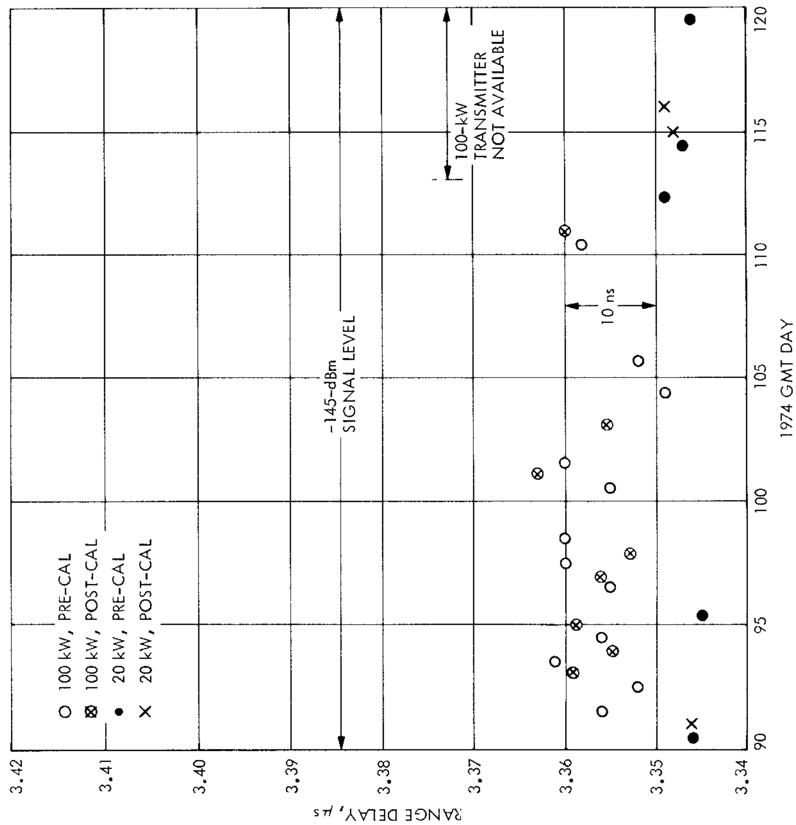

Fig. 9. X-band zero delay range, 1974 Day 90–120 (Mar 31–Apr 30)

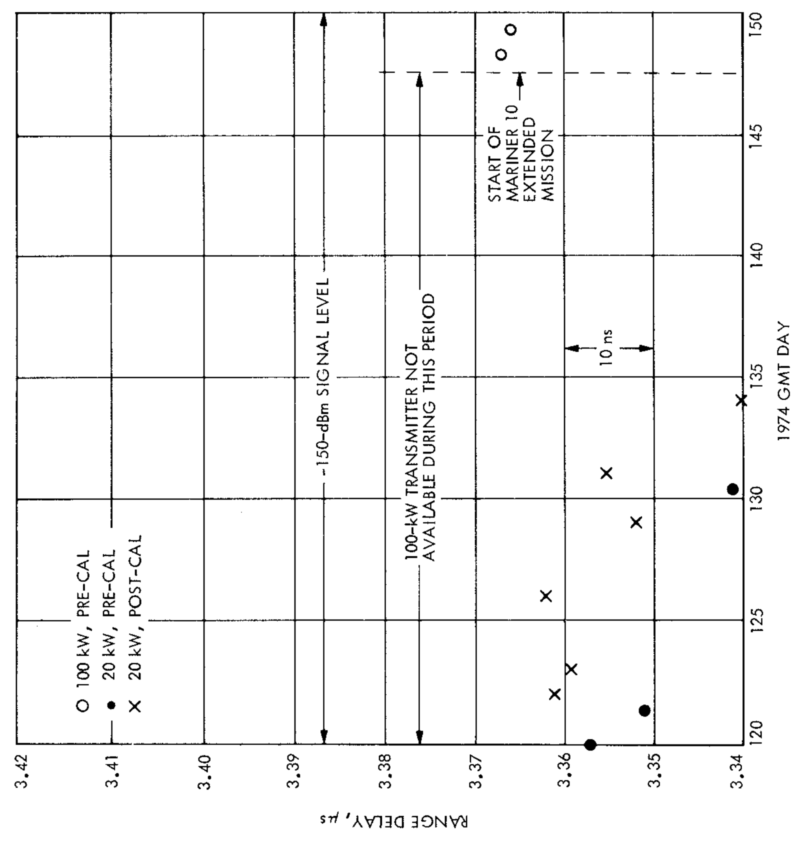

Fig. 10. X-band zero delay range, 1974 Day 120–150 (Apr 30–May 30)